

Washburn, & Rumbaugh (1994). Training
rhesus monkeys (*Macaca mulatta*) using
the computerized test system. *Current*
Primates, 77-84.

NASA-CR-203143

Current Primates

Selected Proceedings of the XIVth Congress
of the International Primatological Society

3 volumes

VOL 3 p 77-84



Université Louis Pasteur
Strasbourg, France



1994

Training rhesus monkeys (*Macaca mulatta*) using the computerized test system

D. A. WASHBURN, D. M. RUMBAUGH

Georgia State University, Atlanta, USA

The Language Research Center's Computerized Test System (LRC-CTS) has proven to be a useful apparatus for comparative investigations of a variety of cognitive, social, "human factors", and bio-behavioral issues. It has been successfully employed at numerous laboratories with humans and a variety of nonhuman primate species. However, the majority of experiments published to date in which the LRC-CTS was used have tested only a small number of research subjects. Whereas this illustrates the power and sensitivity of the research paradigm, it also indicates that more is reported about utilizing the technology than about training the monkeys. The present report reviews the procedures and results from efforts to train additional rhesus monkeys on the LRC-CTS task battery.

Methods

Subjects

Training data for 35 rhesus monkeys (*Macaca mulatta*, one female; age 2 to 9 years; weight 2.4 to 15 kg) are summarized here. The monkeys were tested at Ames Research Center (ARC) in California (n=27) or at the Sonny Carter Life Sciences Laboratory, Georgia State University (n=8, plus the 2 initial monkeys to be trained using the LRC-CTS, Abel and Baker, whose data are not included in this paper). None of the animals had been used in psychological research prior to this project, which began near the end of 1990. During training and testing, all animals had continuous access to water, and none was reduced in weight for purposes of testing.

Apparatus

All animals were trained and tested using the LRC-CTS (Rumbaugh et al., 1989), the prototype of a Psychomotor Test System being developed for space-based performance research. The test system consists of a battery of software tasks and the computer hardware required to administer each test. A computer (initially an XT-compatible, later upgraded to a 386-based system) controlled the generation and presentation of stimuli on a color monitor, detected responses from a standard analog joystick, recorded all data, and delivered pellet

rewards and audio feedback through peripheral devices (hardware and software details can be found in Washburn & Rumbaugh, 1992). Various joystick brands, monitor types and sizes, and computer brands were used at both laboratories with no apparent problems. However, several consistent differences in the apparatus existed between the ARC test environment and that at the Sonny Carter Laboratory. Although the effects these differences might have produced on training efficiency are not analyzed, they are discussed below to illustrate the flexibility of the test system and its application.

At ARC, monkeys were moved from individual vivarium cages to a test room, where they were chaired either in a Primate Products Restraint or a French-designed restraint system (Blanquie et al., 1992). The chairs were then secured to carts, on which all test system apparatus was positioned (including the computer itself, eliminating the need for an external speaker/amplifier). A 300-mg pellet was dispensed after the successful completion of each trial. After the monkeys were acclimated to the restraints, they remained in this test configuration for 4 to 20 days, and then were returned to their home cages for periods of up to 60 days. During a test run, the tasks were available throughout the light cycle (typically 16 hours), during which time the monkeys could work or rest at will.

At the Sonny Carter Life Sciences Laboratory, the monkeys were tested in their individual home cages, which were secured into position at a test station. Each test station contained the monitor, joystick, pellet dispenser, and speaker/amplifier, with wires extending from each through conduit to computers located outside the test rooms (see Washburn & Rumbaugh, 1992). The monkeys reached through the mesh of their cages to manipulate the joystick in accordance with task demands. The animals typically remained at these test stations with access to the tasks 7 days/week, 24 h/day; however, they were periodically given other enrichment activities or paired into compatible dyads for social/exercise periods. As with the ARC animals, the monkeys worked ad libitum within a test day. Although the tasks remained continuously available, almost all trials were performed during the 16-h light period. The monkeys received 97 mg fruit-flavored pellets (Noyes) rewards, and supplemental chow and fruit were provided daily.

Tasks

In contrast to these hardware differences, each animal was trained on identical tasks, regardless of laboratory. The reader is referred elsewhere (e.g., Washburn & Rumbaugh, 1992) for a complete list and description of the battery of 18 tasks used in LRC-CTS training. Each task is menu-based, with options for setting data variables (e.g., subject identification, data collection modes), control variables (e.g., number of trials, intertrial intervals, fixed ratio size), and independent variables (e.g., movement parameters, stimulus characteristics, difficulty levels). The tasks enable an experimenter to collect in ASCII data files a variety of measures including trial production, response accuracy, response latency, response time, and response path (as well as a complete record of parametric settings, date and time stampings, and stimulus descriptions). All programs are written in QuickBasic and use CGA graphics.

In each task, subjects respond to computer-generated stimuli by manipulating a joystick, which results in movement of a cursor (a small, white plus-sign) on the screen. The cursor moves in a direction isomorphic to the angle of joystick displacement. Cursor-target contact is registered as a response, and auditory feedback and reward delivery are presented in accordance with the characteristics of each task.

Training procedure

The order of administration of the tasks was also constant for all animals. The tasks were arranged in a structured curriculum, so that each built inasmuch as possible on the competence produced by the former, so as to establish in each monkey the requisite joystick-manipulation skills and a repertoire of paradigm-specific abilities. Decisions to advance animals from task to task in training were based on specific performance criteria, initially derived from the training and testing data produced by Abel and Baker (Rumbaugh et al., 1989; Washburn et al., 1991). The criteria are very conservative for tasks early in the battery (e.g., SIDE, CHASE) to ensure that the critical joystick skills are mastered. For later tasks (e.g., DMTS), less stringent criteria are employed; the nominal strategy on these tasks is to establish performance at levels significantly better than chance, and then to permit performance to asymptote in subsequent blocks of SELECT task testing. An example of the current criteria for the first tasks in the training curriculum are listed in the Appendix.

Every animal initially received the SIDE task (Rumbaugh et al., 1989), which automatically shaped the naïve monkey to manipulate the joystick for a pellet reward, and subsequently refined the nature of joystick manipulation until the animal could skillfully move the cursor into contact with a 20x32 pixel box on the screen. Upon satisfying SIDE task criteria, an animal was administered the CHASE task in which the small target box moved on screen. Each subsequent task followed in turn, with the decision for advancement or remedial training based in each case upon performance. Some tasks, like SIDE, also adjusted the demands of the task automatically according to a subject's recent performance. This process, termed "titration", was frequently used to introduce subjects to a new procedure. For example, contact with the SIDE target wall in less than 5 s, averaged across 5 consecutive trials, caused the number or size of the target walls to be reduced for the ensuing 5 trials; conversely, poor performance caused the task to be made easier.

Analysis

Space does not permit a summary of performance for the 35 monkeys on each task in the training battery. Rather, we have examined for the present report the general attributes of training success: the animals' progress through the task curriculum, factors that predict training success, and specific training results for two tasks (matching-to-sample, or MTS, and SELECT; see Washburn et al., 1989, 1991).

Results

The principal result from this study is that all 35 rhesus monkeys readily mastered, by use only of the SIDE task, the joystick skills required to respond on tasks in the LRC-CTS battery. Although many animals had failed to complete the curriculum of 18 tasks at the time of this report, all were at relatively advanced points (DMTS or beyond). For animals that had completed the 18-task battery, an average of 117 days of testing were required.

The 35 monkeys reached the stringent criterion for the SIDE task in an average of 2278 trials. Each of these animals exhibited immediate transfer to the moving target in the CHASE task, and required only 3506 trials on average to reach its strict criterion. Of course, these numbers are in many ways determined by the stringency of the criteria. The important datum is the 100% success rate in establishing joystick proficiency using these methods.

The second result pertains to variables that predict success in training, as measured by status in the training curriculum. Each of the 35 animals was coded with respect to its current training status (as of August, 1992). Animals that had completed the 18 tasks in the training battery were given high scores, commensurate with how long they had been finished with training; other animals were assigned a code reflecting how far through the training criteria they had advanced. A hierarchical multiple regression technique was employed, in which variables were entered in approximately the same order that they are available to an experimenter (i.e., age, weight, number of days in training, number of trials performed each day, number of pellets dispensed each day, average TI reversal performance). Only number of trials performed each day (or pellets dispensed, as the two covary and account for almost identical variance) and TI reversal performance (a measure of transfer of learning; see Washburn et al., 1989) were significant predictors of training status. Animal age and weight accounted for less than 5% of the variance together (all of which was attributable to a slight, $r = -.20$, correlation between age and training status). Trials-per-day (mean=753) incremented the predictive model significantly (partial $r^2 = .20$, $p < .05$), but number of days in training, which ranged from 110 to 170, was uncorrelated with training status. TI reversal performance (mean=58%) added significantly to the variance accounted for (partial $r^2 = .21$, $p < .05$), bringing the multiple $R^2 = .47$, $p < .05$.

These two variables predict training success on individual tasks as well as on the battery as a whole. TI reversal performance, for example, was significantly correlated with the number of trials to criterion on the MTS task

($r(33)=-.40$, $p<.05$). The mean number of trials required to meet MTS training criteria was 2106 trials.

Of course, one might note that MTS performance, although significantly better than chance after 2000 trials or so, remained well below optimal levels. What evidence is there to verify the assumption underlying the specified criterion, that performance on a task like MTS would improve to asymptote during SELECT task testing? Analyses of performance on the MTS task administered in the first block of SELECT training (see Appendix) revealed no significant relation between an animal's accuracy level and the terminal level of accuracy during MTS training, nor with the number of trials it had taken to reach criterion during this initial MTS training. Mean accuracy on the MTS task during this first block of SELECT testing was 88% - a significant improvement over the 70% accuracy required by the MTS training criteria ($p<.05$) despite no intervening MTS testing.

Finally, an analysis of task preferences during this block of SELECT training reveals the acquisition of icon-task relations. Icons could be selected from the SELECT menu in any order, but no icon was available for selection a second time until all other tasks had been chosen; consequently, we can determine the percentage of trials in which a task was selected when available. In the first 100 trials of SELECT, the monkeys, on average, respond to the icons at random (SIDE=23%, CHASE=20%, PURSUIT=20%, MTS=18%, DMTS=19%). After only 500 SELECT trials, however, a different pattern is produced (SIDE=35%, CHASE=22%, PURSUIT=18%, MTS=14%, DMTS=11%). Not only does this pattern differ significantly from chance ($\chi^2=17.5$, d.f.=4, $p<.01$), but it also reflects the preference pattern observed for other monkeys after thousands of SELECT trials (Washburn et al., 1991). Ongoing research is exploring the factors that underlie these task preferences.

Discussion

All 35 animals in this sample have mastered the basic joystick skills required for LRC-CTS testing. These behaviors were established despite substantial variability in the configuration of test apparatus across and within laboratories, and with only minimal human intervention. In addition to the ability to manipulate a joystick so as to control the movements of a computer-generated cursor, the animals have developed a repertoire of behavioral proficiencies including the ability to perform pursuit tracking, identity matching-to-sample (which, like all other tasks, is not restricted to any specific set of stimuli), delayed matching, sameness-difference, maze solving,

learning-to-learn (learning set), and signal detection. Thus, the animals are prepared for unprecedented utility as subjects in comparative psychological research.

It is noteworthy that the best predictors of training success are TI reversal performance and trial production. Although the average number of test days required to complete the entire 18-task battery is only four months, it is clear that the best test animals - those most likely to succeed - are monkeys that transfer learning efficiently and work industriously.

The LRC-CTS battery is a useful behavioral research tool, and the present data suggest that animal training on the LRC-CTS procedure and tasks is itself an interesting and efficient process. As the test paradigm is used in additional research, with experiment-specific alterations in the test apparatus, the performance criteria, the training protocol, and the subject species, more will be learned about the technology and about the cognitive competencies of nonhuman and human primates.

Acknowledgments

This research was supported by the National Aeronautics and Space Administration (NASA grant NAG2-438), by HD-06016 from the National Institutes of Health, and by the College of Arts and Sciences of Georgia State University. Data were collected at the Ames Research Center with the assistance of Mary Williams and Leslie Berke of the Bionetics Corporation under contract from NASA. Contact the authors regarding the availability of software and training protocols.

References

- Blanquie, J.P., Florence, G., Riondet, L. Martin, F. & Viso, M. (1992). Development of the restraining system for rhesus monkeys. *Paper presented at the XIVth Congress of the International Primatological Society, Strasbourg.*
- Rumbaugh, D.M., Richardson, W.K., Washburn, D.A., Savage-Rumbaugh, E.S. & Hopkins, W.D. (1989). Rhesus monkeys (*Macaca mulatta*), video tasks, and implications for stimulus-response spatial contiguity. *J. Comp. Psychol.* 103: 32-38.
- Washburn, D.A., Hopkins, W. D. & Rumbaugh, D.M. (1989). Video-task assessment of learning and memory in macaques: Effects of stimulus movement upon performance. *J. Exp. Psychol. Anim. Behav.* 15: 393-400.
- Washburn, D.A., Hopkins, W. D. & Rumbaugh, D.M. (1991). Perceived control in rhesus monkeys (*Macaca mulatta*): Enhanced video-task performance. *J. Exp. Psychol. Anim. Behav.* 17: 123-127.
- Washburn, D.A. & Rumbaugh, D.M. (1992). Testing primates with joystick-based automated apparatus: Lessons from the Language Research Center's Computerized Test System. *Behav. Res. Meth. Instrum. Comput.* 24: 157-164.

Appendix. Training criteria for tasks SIDE to SELECT.

Task	Internal control	Advancement rule	Retreat rule
Side	≠ target walls and size titrated by blocks of 5 trials	200 trials on target 1c: mean response time (RT) < 3 s	None
Chase	None	200 trials min; RT<3 s; drop-outs <10%	to Side if drop-outs >25% or <200 trials
Pursuit	Titration: Collision duration titrated by trial	200 trials min, collision duration 6 s	to Chase if drop-outs >25%, <200 trials
Pursuit	Random: Collision duration randomized by trial	200 trials min, mean percent correct at 3-6 s col. dur.> 60%	to Pursuit/titrated if drops-outs >25%, or if <200 trials
Laser	Shot speed=100: Two shot speeds, manipulated via Train by block	200 trials min, mean ≠ shots < 4	None
TI-67	None	80 full problems	None
MTS	None	200 trials min, mean accuracy over terminal 200 trials 70%	None
DMTS	Titration: Retention interval	Titration retention interval > 10 s.	None
DMTS	Random: Retention interval	200 trials min, mean accuracy over terminal 200 trials > 60%	To DMTS/titrated if accuracy < 30 % or if < 200 trials
Select	Automatic reduction of menu option number	500 problems	None